

Memorandum

Date: January 27, 2014

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To: Scott Ramming (DRCOG)

Re: **Assess Choice Sensitivity to Model Representations of Prices - Status of Work**

1. Background

This memorandum describes the status of the ongoing work as part of Task D of the DRCOG Focus Model Price Sensitivity Refinements study. The task is concerned with assessing choice sensitivity to FOCUS model representations of prices. The work done so far has assessed the skimming and assignment steps of the FOCUS model for their sensitivity to representation of prices in the form of value of time (VOT).

For the purpose of this task, highway and transit networks corresponding to the Northwest Area Mobility Study (NAMS) 2010 FOCUS calibration model run were used. FOCUS tour distribution is not adjusted to match FRTC data. Highway trip tables were not factored after the Trip Time of Day step and prior to highway assignment. The latest version of GISDK developed for the FOCUS model, referred to as FOCUS GISDK, is used. FOCUS executables that were modified to stabilize the randomness in the tour and trip mode choice components are used for this study. This version of the FOCUS 2010 model is referred to by AECOM as Calib36.

The different representations of prices were assessed by comparing the results of highway assignment with traffic counts on toll facilities. Traffic counts during various time periods of the day were provided by DRCOG for the E-470 (at A, B, C, D and E toll plazas), Northwest Parkway (east of Sheridan Parkway, at Main plaza west of Lowell Boulevard, and west of US-287), and I-25 (at 58th Ave. and 70th Ave.).

2. Current Model Representation of Prices

The FOCUS model value of time defaults are \$0.2 per minute (\$12/hour) and \$0.1 per minute (\$6/hour) for peak and off-peak periods, respectively. The toll rates and value of time are assumed to be the same across the three occupancy classes. The value of time for commercial vehicles is assumed to be twice the value of time for passenger vehicles. The resulting daily highway travel demands on the toll facilities in the region are significantly lower than counts, as shown in Table 1 below.

Table 1. FOCUS Calib36 Daily Highway Travel Demand

| Location | Count | FOCUS Calib36 | % Difference from Count |
|--|--------|---------------|-------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | -65% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | -91% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | -72% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | -94% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | -89% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | -99% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | -91% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 9% |
| I-25: 58th Ave | 12,833 | 7,857 | -39% |
| I-25: 70th Ave | 12,809 | 3,217 | -75% |
| Average Corridor Flows | | | |
| E-470 | 23,554 | 4,834 | -79% |
| Northwest Pkwy** | 8,508 | 784 | -91% |
| I-25 | 12,821 | 5,537 | -57% |
| All | 14,961 | 3,719 | -75% |

* Reflects demand in AM and PM periods, as the lanes are closed to all traffic in off-peak. This applies to all FOCUS assignments.

**The mainline toll location volumes are used to estimate average corridor flow for Northwest Parkway

Some of the differences between counts and modeled tolled trips are due to differences in representation of tolling in the FOCUS model from the actual operations on the ground. Some of them are identified as below:

- The toll on I-25 in the FOCUS model is estimated based on distance traveled. The tolls on E-470 and NWP in the model are coded at the gantries, but do not differ by vehicle class or payment method. So the toll on -470 and NWP is not strictly distance-based. Only the vehicles passing through the toll links experience the cost. On ground, the toll charge varies by the time of day (for I-25) or by vehicle class (for E-470) and may not entirely depend on the distance traveled (e.g. the tolls on I-25 are fixed regardless of distance travelled and the tolls on E-470 and Northwest Parkway are charged at main line plaza and ramp plazas). The tolls also differ by method of payment. The E-470 users pay a 20% discounted toll if they have a transponder. The express toll account discount rate is 5% for Northwest Parkway toll payers and 15-30% for I-25 users. The coded tolls in the model are meant to be a weighted average of the tolls charged during the peak or off-peak periods by time interval and payment method (75% of vehicles have transponders).

- I-25 reversible toll lanes are open for traffic between 5:00 am to 10:00 am in southbound direction, and between noon and 3:00 am in northbound direction i.e. the toll-road is open and tolled for 20 hours in a day. In the FOCUS model, the facility is open for AM (6:30 AM to 9:00 AM) and PM (3:00 PM to 7:00 PM) peak periods and is closed to all traffic in the off-peak (9:00 AM to 3:00 PM, and 7:00 PM to 6:30 AM) period . Due to this difference in modeling I-25 toll lanes, I-25 usage is underestimated in the FOCUS model and its response to VOT variation is expected to be limited.

Due to these differences between actual and modeled toll charges, the traffic volumes from model cannot be directly compared to the counts. Regardless, the tests discussed below provide valuable insights into the sensitivity of the FOCUS model to prices.

3. Sensitivity of Highway Assignment to Value of Time (VOT)

Highway demand for each of the 10 time periods is assigned using zero and infinite VOT. This sensitivity test is performed to verify that the results of current values of time in the FOCUS model lie within the range of results from zero (**Test A**) and infinite (**Test B**) VOT. Zero VOT represents the scenario where travelers aim to minimize total cost consisting of tolls and distance-based auto operating costs (i.e., no travel time considerations). Infinite VOT represents the other end of the travel cost objective, where the traveler aims to minimize only travel time (i.e., costs are ignored). The zero and infinite value of time were modeled by using a very low (0.000001) and very high value of time (999999) in the FOCUS model. The assignment with zero VOT results in zero demand for the tolled facilities in the region. The highway assignment results for Test A and Test B are shown in Table 2 below.

Table 2. FOCUS Daily Highway Travel Demand with Assignment using zero and infinite VOT

| Location | Test A | Count | FOCUS Calib36 | Test B | % Difference from Count | % Difference from Calib36 |
|--|--------|--------|---------------|---------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 0 | 38,916 | 13,622 | 129,170 | 232% | 848% |
| E-470: @ Toll Plaza C | 0 | 16,457 | 1,527 | 49,440 | 200% | 3137% |
| E-470: @ Toll Plaza D | 0 | 19,755 | 5,540 | 64,748 | 228% | 1069% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 0 | 26,647 | 1,652 | 72,696 | 173% | 4300% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 0 | 15,993 | 1,831 | 43,236 | 170% | 2261% |
| Northwest Pkwy: e/o Sheridan Pkwy | 0 | 864 | 10 | 4,604 | 433% | 46228% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 0 | 8,508 | 784 | 45,400 | 434% | 5687% |
| Northwest Pkwy: w/o US-287 | 0 | 2,566 | 2,804 | 10,094 | 293% | 260% |
| I-25: 58th Ave | 0 | 12,833 | 7,857 | 22,809 | 78% | 190% |

| | | | | | | |
|-------------------------------|---|--------|-------|--------|------|-------|
| I-25: 70th Ave | 0 | 12,809 | 3,217 | 12,377 | -3% | 285% |
| Average Corridor Flows | | | | | | |
| E-470 | 0 | 23,554 | 4,834 | 71,858 | 205% | 1386% |
| Northwest Pkwy | 0 | 8,508 | 784 | 45,400 | 434% | 5687% |
| I-25 | 0 | 12,821 | 5,537 | 17,593 | 37% | 218% |
| All | 0 | 14,961 | 3,719 | 44,950 | 200% | 1109% |

Several additional VOT tests within highway assignment were conducted. **Test C** assigned highway demand using twice the value of time in the current DRCOG FOCUS model (i.e., \$24/hour and \$12/hour during peak and off-peak periods, respectively). The resulting corridor demands are shown in Table 3. The demand on E-470 and Northwest Parkway facilities with twice the VOT is significantly closer to counts than in Calib36.

Table 3. FOCUS Daily Highway Travel Demand with Assignment using twice Calib36 VOT

| Location | Count | FOCUS Calib36 | Test C | % Difference from Count | % Difference from Calib36 |
|--|--------|---------------|--------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | 61,455 | 58% | 351% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | 24,798 | 51% | 1524% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | 55,023 | 179% | 893% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | 37,644 | 41% | 2178% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | 32,065 | 101% | 1651% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | 5,753 | 566% | 57787% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | 24,242 | 185% | 2990% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 10,290 | 301% | 267% |
| I-25: 58th Ave | 12,833 | 7,857 | 28,238 | 120% | 259% |
| I-25: 70th Ave | 12,809 | 3,217 | 10,232 | -20% | 218% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 4,834 | 42,197 | 79% | 773% |
| Northwest Pkwy | 8,508 | 784 | 24,242 | 185% | 2990% |
| I-25 | 12,821 | 5,537 | 19,235 | 50% | 247% |
| All | 14,961 | 3,719 | 28,558 | 91% | 668% |

The highway assignment was also tested with using different VOT by income category – low, medium and high. The FOCUS procedure was modified as follows to assign highway demand by income:

The FOCUS stored procedure to select trips to be written to TransCAD was modified to write out trips by the three income categories. The Highway Time of Day GISDK script was developed to combine these trip tables into the same matrix files that are assigned (with extra matrix cores). The highway assignment script was modified to assign trips by income. The procedure was tested by duplicating the same link flows using the same value of time as in the DRCOG FOCUS model for each income category (as a control case).

Several sensitivity tests, as described below, were performed using different VOT values by income.

Test D: The DRCOG FOCUS value of time defaults of \$12/hour and \$6/hour for peak and off-peak periods were used for medium income, but the high and low income VOT were assumed to be equal to those from the **COMPASS 4.0 model**. The high income VOT was assumed to be twice the VOT for medium income (\$24/hour during peak and \$12/hour during off-peak), and the low income VOT was assumed to be two-thirds of the medium income VOT (\$8/hour during peak and \$4/hour during off-peak). The COMPASS 4.0 model does not vary VOT by income during off-peak period. However, as mentioned above, off-peak value of time was assumed to be half that of peak value of time for sensitivity testing. VOT for airport trips was assumed to be \$30/hour during peak and off-peak periods. The results are shown in Table 4. The E-470 and Northwest Parkway demand increases by a magnitude of three to five folds from using the COMPASS model value of time, thus bringing them closer to counts. However, I-25 toll usage stays at Calib36 levels.

Table 4. FOCUS Daily Highway Travel Demand with Assignment using VOT from COMPASS Model

| Location | Count | FOCUS Calib36 | Test D | % Difference from Count | % Difference from Calib36 |
|--|--------|---------------|--------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | 24,968 | -36% | 83% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | 11,170 | -32% | 631% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | 19,171 | -3% | 246% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | 11,458 | -57% | 593% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | 8,960 | -44% | 389% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | 352 | -59% | 3444% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | 4,381 | -49% | 458% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 3,978 | 55% | 42% |
| I-25: 58th Ave | 12,833 | 7,857 | 7,715 | -40% | -2% |
| I-25: 70th Ave | 12,809 | 3,217 | 3,343 | -74% | 4% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 4,834 | 15,145 | -36% | 213% |
| Northwest Pkwy | 8,508 | 784 | 4,381 | -49% | 458% |
| I-25 | 12,821 | 5,537 | 5,529 | -57% | 0% |

| | | | | | |
|-----|--------|-------|-------|------|------|
| All | 14,961 | 3,719 | 8,352 | -44% | 125% |
|-----|--------|-------|-------|------|------|

Test E: The VOT based on the analysis done as part of Task A (memo titled “US 36 Stated Preference Survey Value of Time Analysis”) was used in the Highway Assignment. Peak VOT was \$12.6/hour and off-peak VOT was \$14.4/hour for all income categories. VOT for DIA trips was assumed to be 95% of the medium income VOT during peak periods and 115% of the medium income VOT during off-peak periods. The results from this test are shown in Table 5. The E-470 and Northwest Parkway demands get a boost (30-75%) from using the COMPASS model value of time, but not enough to bring them closer to counts. I-25 toll usage stays at Calib36 levels.

Table 5. FOCUS Daily Highway Travel Demand with Assignment using VOT from US 36 Stated Preference Survey

| Location | Count | FOCUS Calib36 | Test E | % Difference from Count | % Difference from Calib36 |
|--|--------|---------------|--------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | 16,824 | -57% | 24% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | 4,722 | -71% | 209% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | 11,857 | -40% | 114% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | 3,806 | -86% | 130% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | 5,189 | -68% | 183% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | 75 | -91% | 656% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | 1,063 | -88% | 35% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 5,449 | 112% | 94% |
| I-25: 58th Ave | 12,833 | 7,857 | 7,931 | -38% | 1% |
| I-25: 70th Ave | 12,809 | 3,217 | 3,235 | -75% | 1% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 4,834 | 8,480 | -64% | 75% |
| Northwest Pkwy | 8,508 | 784 | 1,063 | -88% | 35% |
| I-25 | 12,821 | 5,537 | 5,583 | -56% | 1% |
| All | 14,961 | 3,719 | 5,042 | -66% | 36% |

Test F: VOT was varied by **purpose and income** within the FOCUS highway assignment. The cost and IVTT coefficients in the Tour Mode Choice model by purpose and income were reviewed. VOT for low, medium and high income home-based work (HBW) trips were established based on the IVTT and cost coefficients. VOT for school (HBS), escort (HBE), home-based other (HBO) tours and work based subtrips were pivoted off the three HBW purpose VOTs. In essence, the VOT assumptions in the Tour Mode Choice were reflected in this test. The purpose-income categories were assigned to the nearest one of the three VOT categories (\$5/hour, \$10/hour, and \$15/hour), with exceptions such as HBE and work subtrip that were rounded up (ceiling operation) to the higher VOT. The HBO model includes income stratification. The Tour Mode Choice assumes a single value of time for low and medium income

HBO tours, and a different VOT for high income HBO tours. Test F assumes a single value of time of \$5/hr for HBO tours made by all three income classes.

The FOCUS stored procedure to select trips to be written to TransCAD was modified to write out trips by three purpose-income categories. The three VOT categories (\$5/hour, \$10/hour, and \$15/hour) for various purpose and income combinations are shown in Table 6, along with VOT used in the Tour Mode Choice.

The highway assignment results are shown in Table 7. Tests C, D, E and F suggest that the FOCUS highway assignment is highly sensitive to value of time by purpose and income. Test D is better for E-470, and for the NWP mainline tolls. Test F is better for the NWP ramp tolls. The variation in the I-25 Express Lanes demand can be attributed to model noise. The demand in the I-25 general purpose lanes is higher in Test F than in Test D in off-peak period, lower in peak period, and higher at the daily level.

Table 6. VOT by Purpose and Income

| Purpose | Income | Tour Mode Choice | | Test F | |
|--------------------|--------|------------------|--------------|-------------|--------------|
| | | VOT (\$/hr) | VOT (\$/min) | VOT (\$/hr) | VOT (\$/min) |
| HBW | Low | 4.80 | 0.08 | 5.00 | 0.08 |
| | Medium | 10.08 | 0.17 | 10.00 | 0.16 |
| | High | 14.29 | 0.24 | 15.00 | 0.24 |
| HBS | | 3.80 | 0.06 | 5.00 | 0.08 |
| HBE | | 6.00 | 0.10 | 10.00 | 0.16 |
| HBO | Low | 2.38 | 0.04 | 5.00 | 0.08 |
| | Medium | 2.38 | 0.04 | 5.00 | 0.08 |
| | High | 4.55 | 0.08 | 5.00 | 0.08 |
| Work Based Subtour | | 6.87 | 0.11 | 10.00 | 0.16 |

Table 7. FOCUS Daily Highway Travel Demand with Assignment using VOT by Purpose and Income

| Location | Count | FOCUS Calib36 | Test F | % Difference from Count | % Difference from Calib36 |
|--|--------|---------------|--------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | 15,341 | -61% | 13% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | 7,925 | -52% | 419% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | 14,794 | -25% | 167% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | 7,045 | -74% | 326% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | 6,910 | -57% | 277% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | 181 | -79% | 1724% |

| | | | | | |
|--|--------|-------|--------|------|------|
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | 2,261 | -73% | 188% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 3,672 | 43% | 31% |
| I-25: 58th Ave | 12,833 | 7,857 | 7,126 | -44% | -9% |
| I-25: 70th Ave | 12,809 | 3,217 | 2,989 | -77% | -7% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 4,834 | 10,403 | -56% | 115% |
| Northwest Pkwy | 8,508 | 784 | 2,261 | -73% | 188% |
| I-25 | 12,821 | 5,537 | 5,058 | -61% | -9% |
| All | 14,961 | 3,719 | 5,907 | -61% | 59% |

4. Sensitivity of Highway Skimming to Value of Time (VOT)

Test F in the section above tested the sensitivity of the FOCUS highway assignment to VOT by purpose and income. This section discusses the sensitivity of the FOCUS skimming process to VOT by purpose and income.

The highway skims were generated using VOT by different income-purpose categories (Table 6). The Generalized Time calculation was modified, using a GISDK script, to read in the skims by the three purpose-income categories. With the skimming procedure modified to consider VOT by purpose and income, tour mode choice through highway assignment were re-run using existing (fixed) activity patterns and locations. Two sets of highway assignments were run: Test G and Test H.

Test G: Highway Skimming was done using VOT by purpose and income and the new highway trips were assigned using DRCOG FOCUS default VOT (\$12/hour during peak and \$6/hour during off-peak for all trips). The results, shown in Table 8, suggest that the FOCUS skimming and tour mode choice through trip table generation process is generally insensitive to value of time changes. The zone-to-zone skim values change slightly for a number of interchanges, but these changes do not appear to have much impact on the tour or trip mode choice, intermediate stop locations, or time of day results. As seen in Table 8, the resulting toll facility volumes do not deviate significantly from Calib36.

Table 8. FOCUS Daily Highway Travel Demand with Skimming using VOT by Purpose and Income

| Location | Count | FOCUS Calib36 | Test G | % Difference from Count | % Difference from Calib36 |
|--|--------|---------------|--------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | 14,202 | -64% | 4% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | 1,598 | -90% | 5% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | 5,850 | -70% | 6% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | 1,759 | -93% | 6% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | 1,901 | -88% | 4% |

| | | | | | |
|--|--------|-------|-------|------|-----|
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | 11 | -99% | 10% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | 834 | -90% | 6% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 2,928 | 14% | 4% |
| I-25: 58th Ave | 12,833 | 7,857 | 7,942 | -38% | 1% |
| I-25: 70th Ave | 12,809 | 3,217 | 3,146 | -75% | -2% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 4,834 | 5,062 | -79% | 5% |
| Northwest Pkwy | 8,508 | 784 | 834 | -90% | 6% |
| I-25 | 12,821 | 5,537 | 5,544 | -57% | 0% |
| All | 14,961 | 3,719 | 3,813 | -75% | 3% |

Test H: Highway Skimming was done using VOT by purpose and income and the new highway trips were assigned using VOT by purpose and income (as used for highway skimming). The results, shown in Table 9, are compared to Test F to show the incremental impact of skimming using VOT by purpose and income. The results suggest that varying VOT by purpose and income in both skimming and assignment processes does not improve upon varying VOT by purpose and income in the assignment process alone. This confirms the above finding that value of time changes in FOCUS skimming to not have a significant impact on the trip tables used for the highway assignment.

Table 9. FOCUS Daily Highway Travel Demand with Skimming and Assignment using VOT by Purpose and Income

| Location | Count | Test F | Test H | % Difference from Count | % Difference from Test F |
|--|--------|--------|--------|-------------------------|--------------------------|
| E-470: @ Toll Plaza A | 38,916 | 15,341 | 14,212 | -63% | -7% |
| E-470: @ Toll Plaza C | 16,457 | 7,925 | 7,840 | -52% | -1% |
| E-470: @ Toll Plaza D | 19,755 | 14,794 | 14,791 | -25% | 0% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 7,045 | 6,740 | -75% | -4% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 6,910 | 6,838 | -57% | -1% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 181 | 204 | -76% | 13% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 2,261 | 2,251 | -74% | 0% |
| Northwest Pkwy: w/o US-287 | 2,566 | 3,672 | 3,133 | 22% | -15% |
| I-25: 58th Ave | 12,833 | 7,126 | 6,750 | -47% | -5% |
| I-25: 70th Ave | 12,809 | 2,989 | 2,849 | -78% | -5% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 10,403 | 10,084 | -57% | -3% |

| | | | | | |
|----------------|--------|-------|-------|------|-----|
| Northwest Pkwy | 8,508 | 2,261 | 2,251 | -74% | 0% |
| I-25 | 12,821 | 5,058 | 4,799 | -63% | -5% |
| All | 14,961 | 5,907 | 5,711 | -62% | -3% |

In an attempt to understand the negligible impact of VOT in skimming on toll facility demands, the highway skims by the three income-purpose categories (and hence the three VOT categories) are assessed. Minimum impedance paths are built using skims generated with different VOT. Two sets of O-D nodes are chosen to test the sensitivity of the path's likelihood to include the extent of one or more toll corridors (Northwest Parkway, I-225 and E-470). Table 10 below shows the distance, time and breakdown of costs for the minimum impedance path based on peak period impedance. Figure 1 shows the minimum impedance paths for the node-pair 7035-12160 in Calib36, Test A and Test B scenarios. Paths are built for the AM2 period (7:00 AM to 8:00 AM). Figure 2 shows the minimum impedance paths for the node-pair 7035-12160 in Calib36 and Test C scenarios. Figure 3 shows the minimum impedance paths for the node-pair 7035-12160 by income category in Test G/H scenarios. Node 7035 represents the intersection of E 120th Avenue and Colorado Boulevard in Thornton. Node 12160 represents the intersection of Colfax Avenue and N Speer Boulevard in Denver CBD. In the zero VOT case (Test A), the path avoids I-25 as the objective is to minimize the toll cost and distance but not travel time. Conversely, the path with infinite VOT (Test B) tries to minimize the travel time with no regard for toll cost. The path in the Calib36 scenario is a mix of arterials (Colorado Boulevard and Thornton Parkway), and tolled and un-tolled highway since the objective is to minimize the composite impedance of toll, travel time and distance costs. The path in Test C (twice Calib36 VOT) is similar to that in Test B. The path of low income travelers in Test G is similar to that with zero VOT, while that of high income travelers is similar to that with infinite VOT. The medium income path is similar to that in Calib36.

Figures 4, 5 and 6 show the paths for the same scenarios for the 7122-14878 node pair. Node 7122 represents the intersection of Northwest Parkway and S 96th St in Louisville. Node 14878 represents the intersection of E 56th Ave and E-470. The findings for this node pair are similar those for the 7035-12160 node pair. In the zero VOT case, the path avoids E-470 in order to minimize toll cost and avoids the extra distance to travel by US-36. Conversely, the path with infinite VOT makes the most use of E-470 and Northwest Parkway. The path in the Calib36 scenario is a result of minimizing the composite impedance. The path in Test C is similar to the path in Test B. The path of low and medium income travelers in Test G is similar to the Calib36 path, while that of high income travelers is similar to the path in Test B.

Table 10. Minimum Impedance Path Costs – Sensitivity to VOT

| AM2 Highway Skims - Sensitivity to Value of Time | | | | | | | | | | | |
|---|------------------|------------|----------------|----------|---------------|----------|---------------------------------|-------|-------|--|--|
| Shortest paths based on Imp_Pk | | | | | | | | | | | |
| Nodes | | | Calib36 | | | | Calib36 Skims by incpurp | | | | |
| O | D | | original | zeroVOT | infiniteVOT | twiceVOT | LI | MI | HI | | |
| 7035 | 12160 | VOT | 0.2 | 0.000001 | 999999 | 0.4 | | | | | |
| 120th | Colfax and Speer | DIST | 15.66 | 13.54 | 15.63 | 15.91 | 14.06 | 15.28 | 15.91 | | |
| Thornton | CBD | Time | 31.99 | 37.92 | 27.06 | 31.09 | 36.09 | 32.55 | 31.09 | | |
| | | TollCost | 0 | 0 | 19.2 | 0 | 0.00 | 0 | 0 | | |
| | | AutoOpCost | 2.74 | 2.03 | 2.88 | 2.95 | 2.11 | 2.63 | 2.95 | | |
| | | Totcost | 2.74 | 2.03 | 22.08 | 2.95 | 2.11 | 2.63 | 2.95 | | |
| | | Imp_Pk | 9.14 | 2.03 | 27,059,995.02 | 15.39 | 5.00 | 7.84 | 10.41 | | |
| Nodes | | | | | | | | | | | |
| O | D | | Calib36 | | | | Calib36 Skims by incpurp | | | | |
| | | | original | zeroVOT | infiniteVOT | twiceVOT | LI | MI | HI | | |
| 7122 | 14878 | VOT | 0.2 | 0.000001 | 999999 | 0.4 | | | | | |
| NW Pkwy at 96th | 56th & E-470 | DIST | 29.89 | 31.66 | 30.72 | 30.09 | 29.88 | 29.88 | 30.71 | | |
| Louisville | Adams | Time | 48.77 | 64.37 | 24.06 | 24.41 | 49.12 | 48.89 | 28.75 | | |
| | | TollCost | 0 | 0 | 4.91 | 4.91 | 0.00 | 0 | 3.72 | | |
| | | AutoOpCost | 5.13 | 4.76 | 6.08 | 5.85 | 5.08 | 5.11 | 5.74 | | |
| | | Totcost | 5.13 | 4.76 | 10.99 | 10.76 | 5.08 | 5.11 | 9.46 | | |
| | | Imp_Pk | 14.88 | 4.76 | 24,059,986.93 | 20.52 | 9.01 | 12.93 | 16.36 | | |

Figure 1. Minimum Impedance Paths for the Node-Pair 7035-12160 in Calib36, Test A and Test B Scenarios

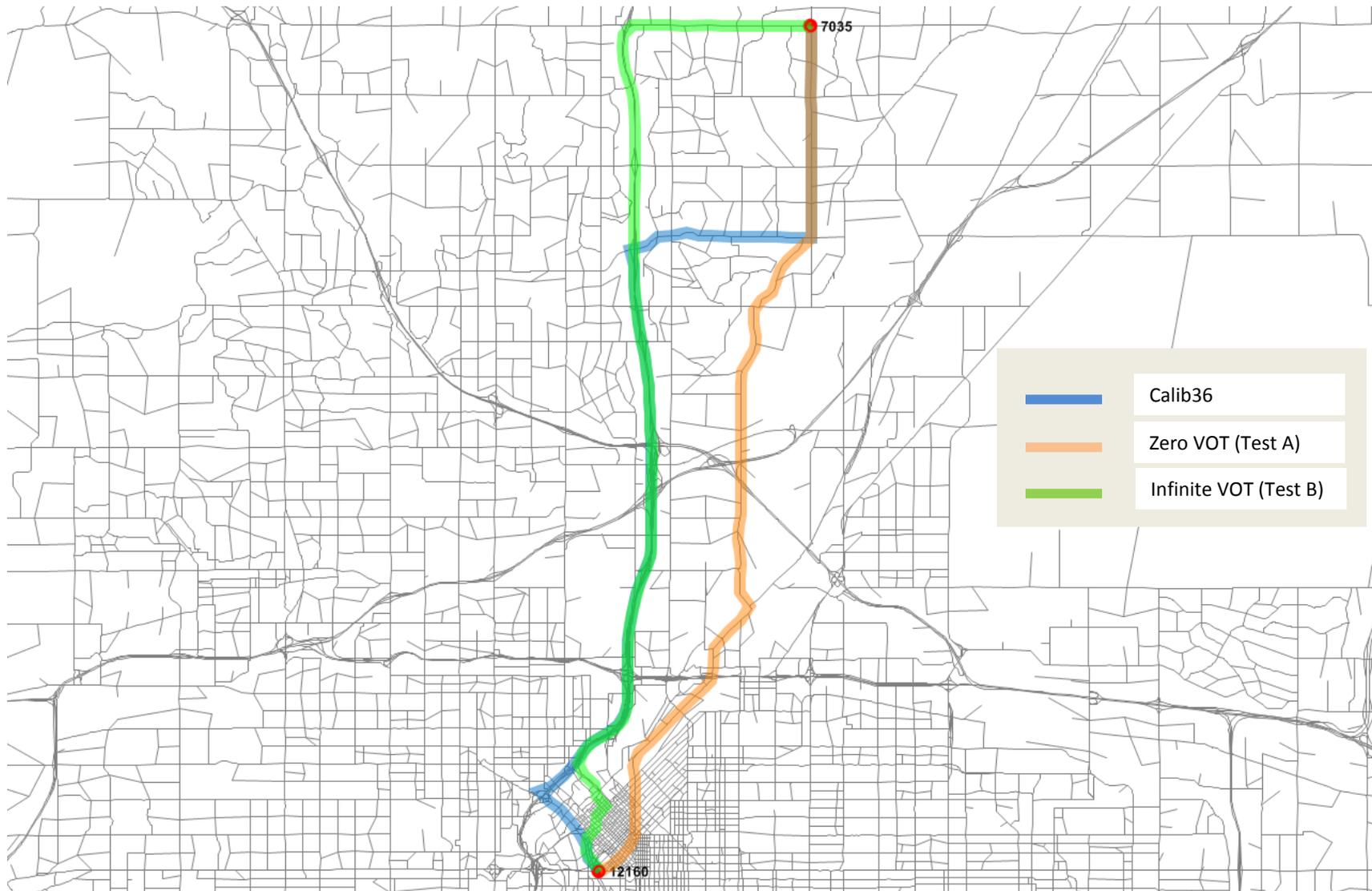


Figure 2. Minimum Impedance Paths for the Node-Pair 7035-12160 in Calib36 and Test C Scenarios

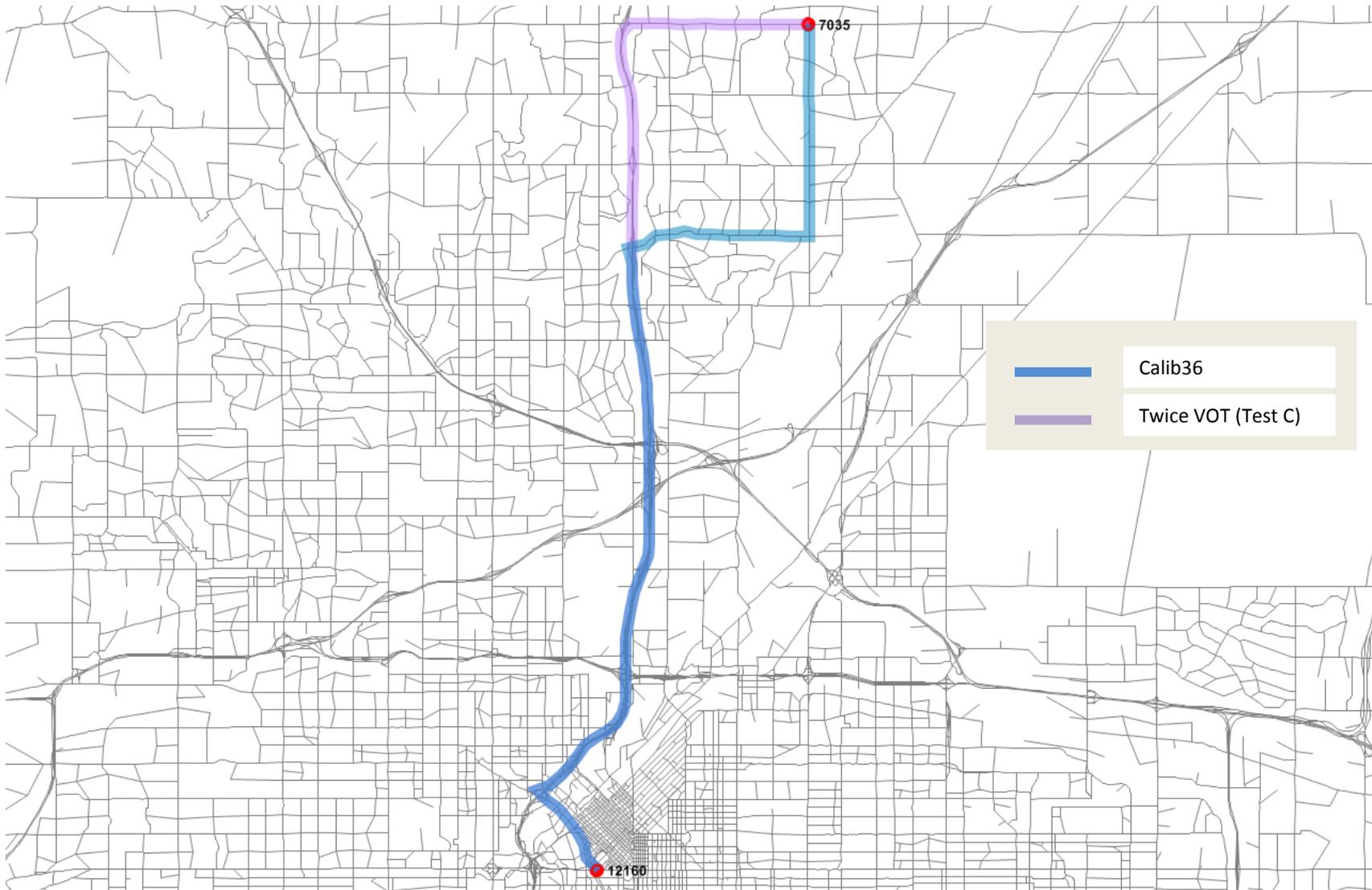


Figure 3. Minimum Impedance Paths for the Node-Pair 7035-12160 by Income Category in Test G Scenario

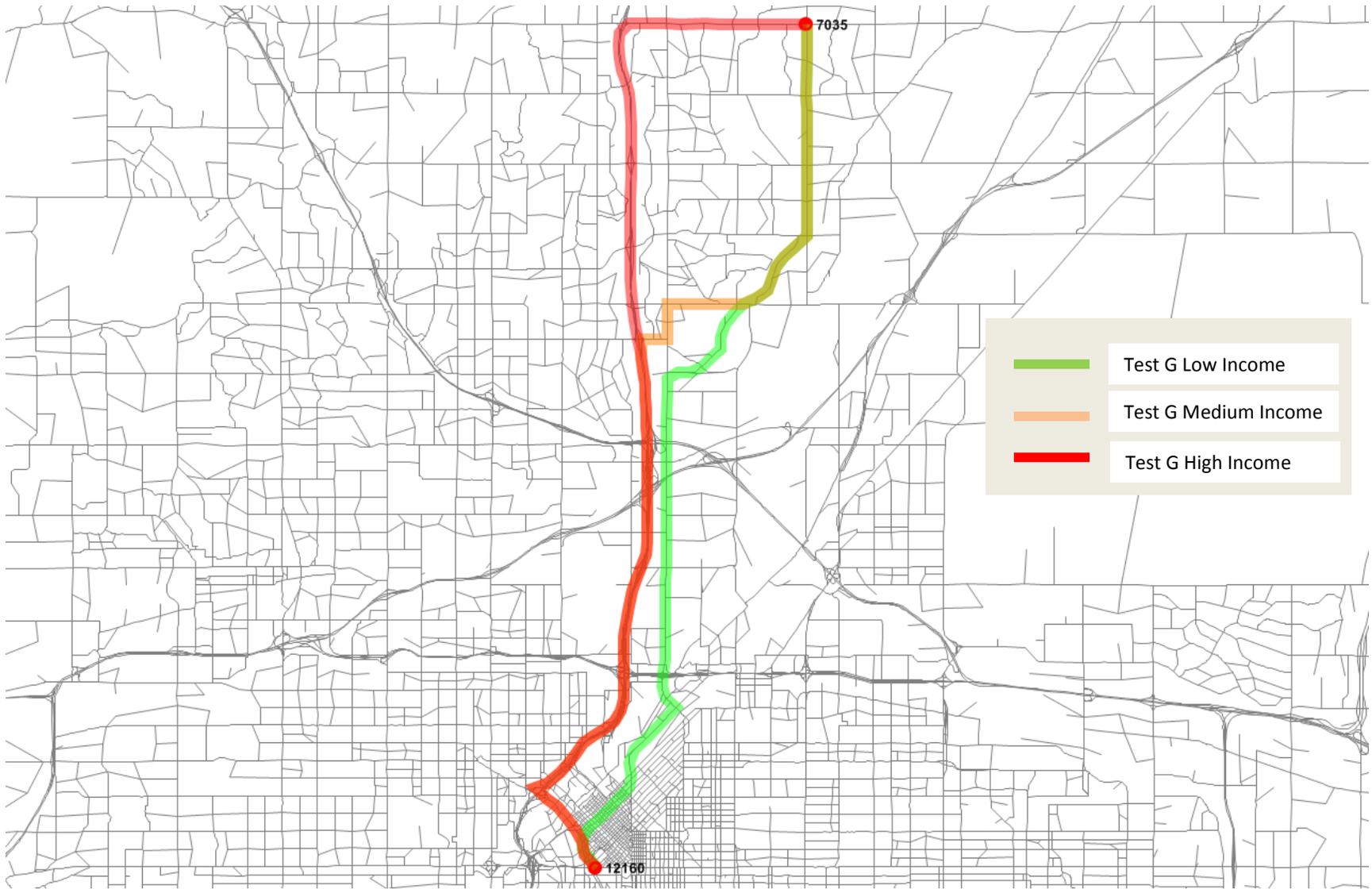


Figure 4. Minimum Impedance Paths for the Node-Pair 7122-14878 in Calib36, Test A and Test B Scenarios

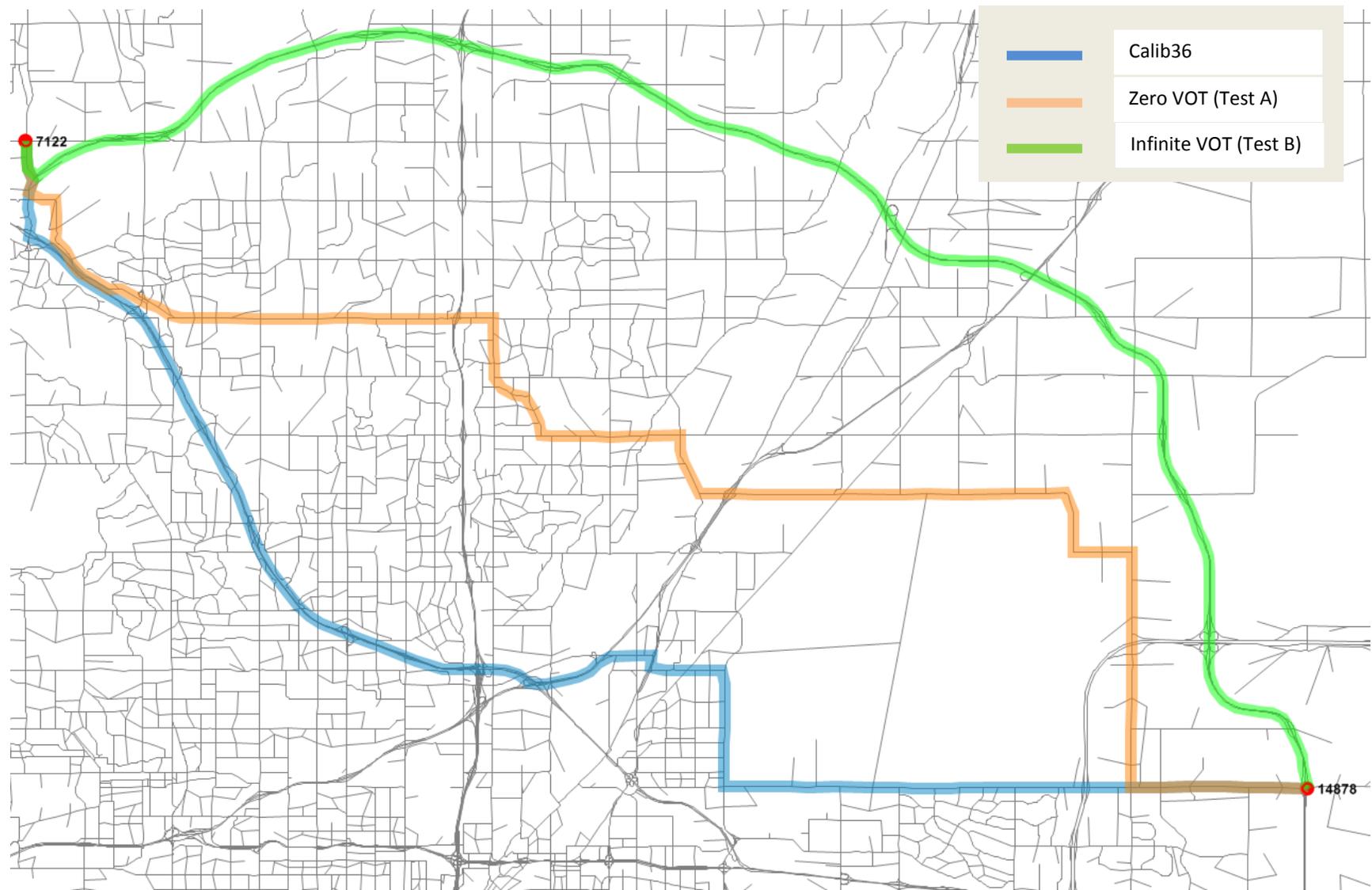


Figure 5. Minimum Impedance Paths for the Node-Pair 7122-14878 in Calib36 and Test C Scenarios

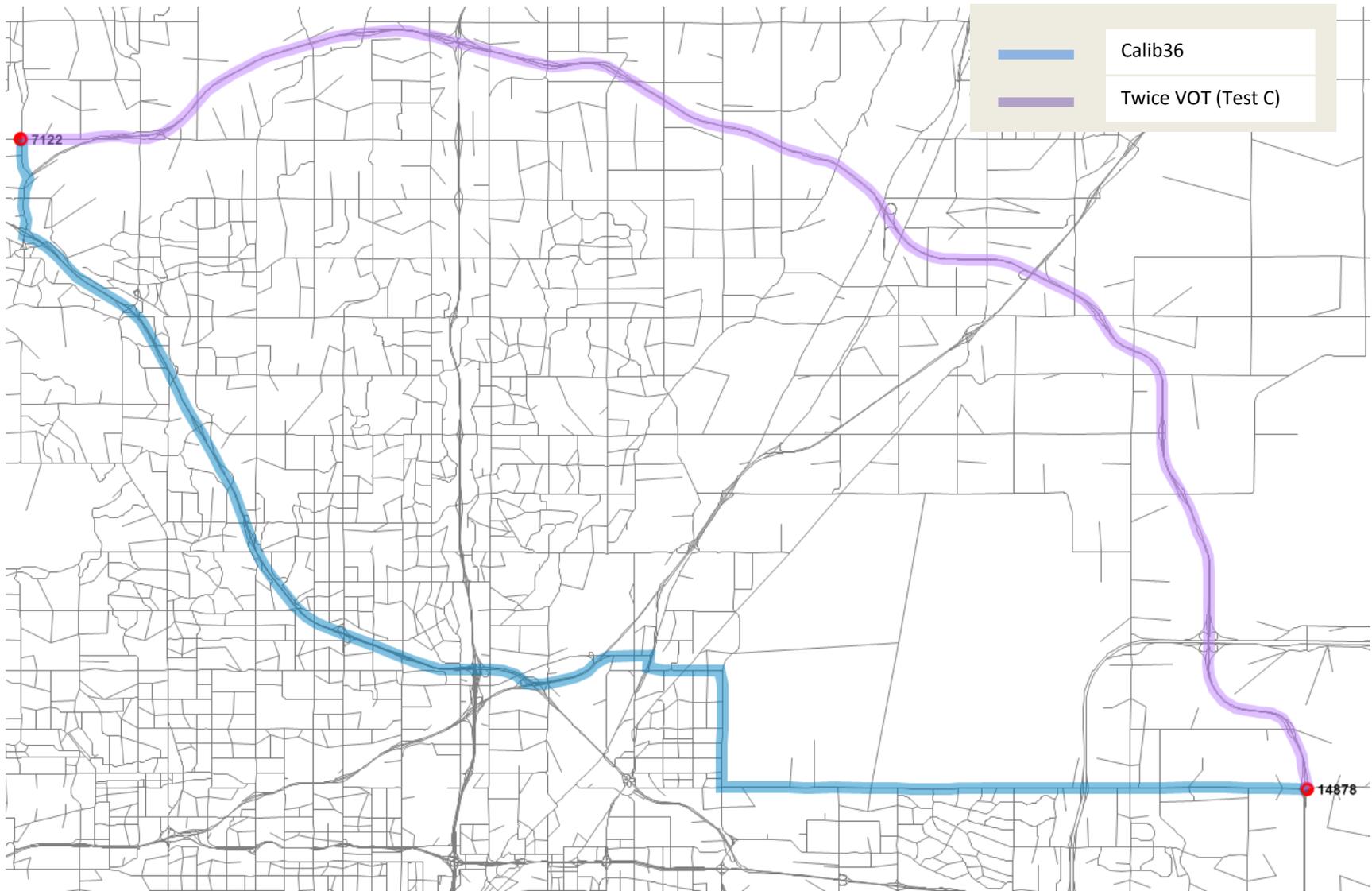
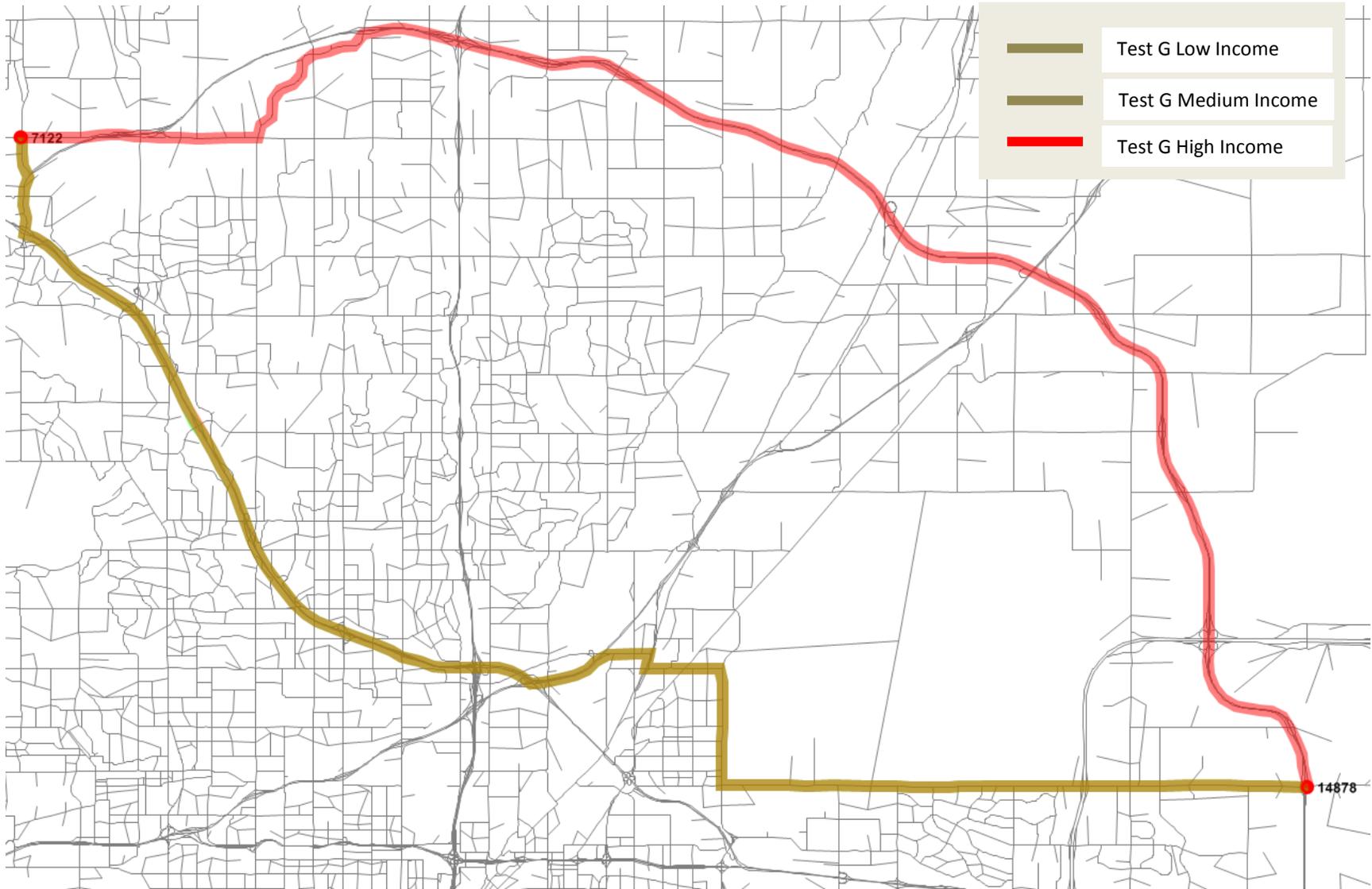


Figure 6. Minimum Impedance Paths for the Node-Pair 7122-14878 by Income Category in Test G Scenario



As discussed above, the highway skims are sensitive to VOT. As the next step, the tour and trip mode choice were assessed for the impact of change in skims. The variation of VOT by income and purpose in the highway skimming process was found to not have a significant impact on the mode choice. The difference in skims does not change the generalized time values enough to make an impact on tour mode choice, trip distribution (Intermediate Stop Location) and trip mode choice. Table 11 shows the Tour and Trip Mode Choice by income categories. Low income is defined as income < \$35,000, medium income as income between \$35,000 and \$100,000, and high income as income greater than \$100,000. The difference in total daily person trips traveling by auto (drive alone, Shared Ride 2 and Shared Ride 3+) increases by ~300. In summary, the highway paths were changing in response to changing VOT, but the change in paths was not significant enough to change the mode chosen for the tour and trip. Hence, the variation of VOT in skimming process does not change assigned toll demands. However, a change in VOT in the network assignment results in different path chosen for the trip, and hence a change in highway volumes.

Table 11. Tour and Trip Mode Choice with Highway Skimming using VOT varied by Purpose and Income

| | Low Income | | | Medium Income | | | High Income | | | All | | |
|------------------|------------|-----------|--------------|---------------|-----------|--------------|-------------|-----------|--------------|-----------|-----------|--------------|
| Tour Mode | Calib36 | Test G/H* | % Difference | Calib36 | Test G/H | % Difference | Calib36 | Test G/H | % Difference | Calib36 | Test G/H | % Difference |
| Bike | 18,825 | 18,826 | 0.0% | 17,780 | 17,790 | 0.1% | 5,012 | 5,004 | -0.2% | 41,617 | 41,620 | 0.0% |
| Drive Alone | 331,320 | 331,914 | 0.2% | 955,069 | 956,085 | 0.1% | 406,555 | 407,971 | 0.3% | 1,692,944 | 1,695,970 | 0.2% |
| Drive to Transit | 4,892 | 4,861 | -0.6% | 14,831 | 14,791 | -0.3% | 7,423 | 7,333 | -1.2% | 27,146 | 26,985 | -0.6% |
| School Bus | 25,004 | 25,001 | 0.0% | 51,983 | 51,973 | 0.0% | 27,479 | 27,478 | 0.0% | 104,466 | 104,452 | 0.0% |
| Shared Ride 2 | 232,253 | 232,108 | -0.1% | 568,942 | 568,539 | -0.1% | 223,398 | 222,870 | -0.2% | 1,024,593 | 1,023,517 | -0.1% |
| Shared Ride 3+ | 152,624 | 152,301 | -0.2% | 404,870 | 404,342 | -0.1% | 176,164 | 175,374 | -0.4% | 733,658 | 732,017 | -0.2% |
| Walk | 137,927 | 137,917 | 0.0% | 149,975 | 149,972 | 0.0% | 44,032 | 44,030 | 0.0% | 331,934 | 331,919 | 0.0% |
| Walk to Transit | 34,374 | 34,291 | -0.2% | 25,942 | 25,900 | -0.2% | 5,542 | 5,545 | 0.1% | 65,858 | 65,736 | -0.2% |
| | Low Income | | | Medium Income | | | High Income | | | All | | |
| Trip Mode | Calib36 | Test G/H | % Difference | Calib36 | Test G/H | % Difference | Calib36 | Test G/H | % Difference | Calib36 | Test G/H | % Difference |
| Bike | 43,565 | 43,398 | -0.4% | 44,995 | 45,287 | 0.6% | 14,685 | 14,652 | -0.2% | 103,245 | 103,337 | 0.1% |
| Drive Alone | 1,020,040 | 1,021,998 | 0.2% | 2,907,258 | 2,909,974 | 0.1% | 1,279,999 | 1,283,488 | 0.3% | 5,207,297 | 5,215,460 | 0.2% |
| Drive to Transit | 8,456 | 8,478 | 0.3% | 25,987 | 25,813 | -0.7% | 12,779 | 12,716 | -0.5% | 47,222 | 47,007 | -0.5% |
| School Bus | 42,088 | 41,959 | -0.3% | 86,675 | 86,502 | -0.2% | 46,555 | 46,755 | 0.4% | 175,318 | 175,216 | -0.1% |
| Shared Ride 2 | 501,556 | 501,392 | 0.0% | 1,229,567 | 1,228,778 | -0.1% | 481,924 | 480,035 | -0.4% | 2,213,047 | 2,210,205 | -0.1% |
| Shared Ride 3+ | 409,797 | 409,380 | -0.1% | 1,103,883 | 1,102,617 | -0.1% | 493,683 | 491,846 | -0.4% | 2,007,363 | 2,003,843 | -0.2% |
| Walk | 373,485 | 376,996 | 0.9% | 424,328 | 426,644 | 0.5% | 130,109 | 130,842 | 0.6% | 927,922 | 934,482 | 0.7% |
| Walk to Transit | 72,710 | 67,807 | -6.7% | 25,942 | 52,555 | -0.2% | 5,542 | 5,545 | 0.1% | 65,858 | 65,736 | -0.2% |

* The results are valid for Test G and Test H. The mode choice in Tests G and H is the same, since the skims are the same

5. Highway Assignment Parameters

In an attempt to investigate the reasons for low demand on all toll roads, the overall demand on highways in the region was compared to traffic counts and screenlines. The purpose of this comparison is not to validate the model, but to check whether the trips assigned in the model are not significantly lower than the counts at a large east-west and north-south screenlines through the tolled facilities in the region. The 2010 highway networks received from DRCOG include counts for AM, PM, MD and EL periods. According to DRCOG, the EL counts are in error. Hence, only the AM, MD and PM counts were used to assess the model volumes at the screenlines. For the purpose of this analysis, these are assumed to be consistent with the FOCUS model time periods AM, MD and PM. Four screenlines were drawn to capture E-W and N-S flows. The E-W screenlines were drawn north and south of I-70. The N-S screenlines were drawn west and east of CBD. The screenlines are illustrated in Figure 7. The counts and model demand in Calib36 are shown in Table 12.

Figure 7. Screenlines to compare FOCUS Calib36 Highway Demand against Counts

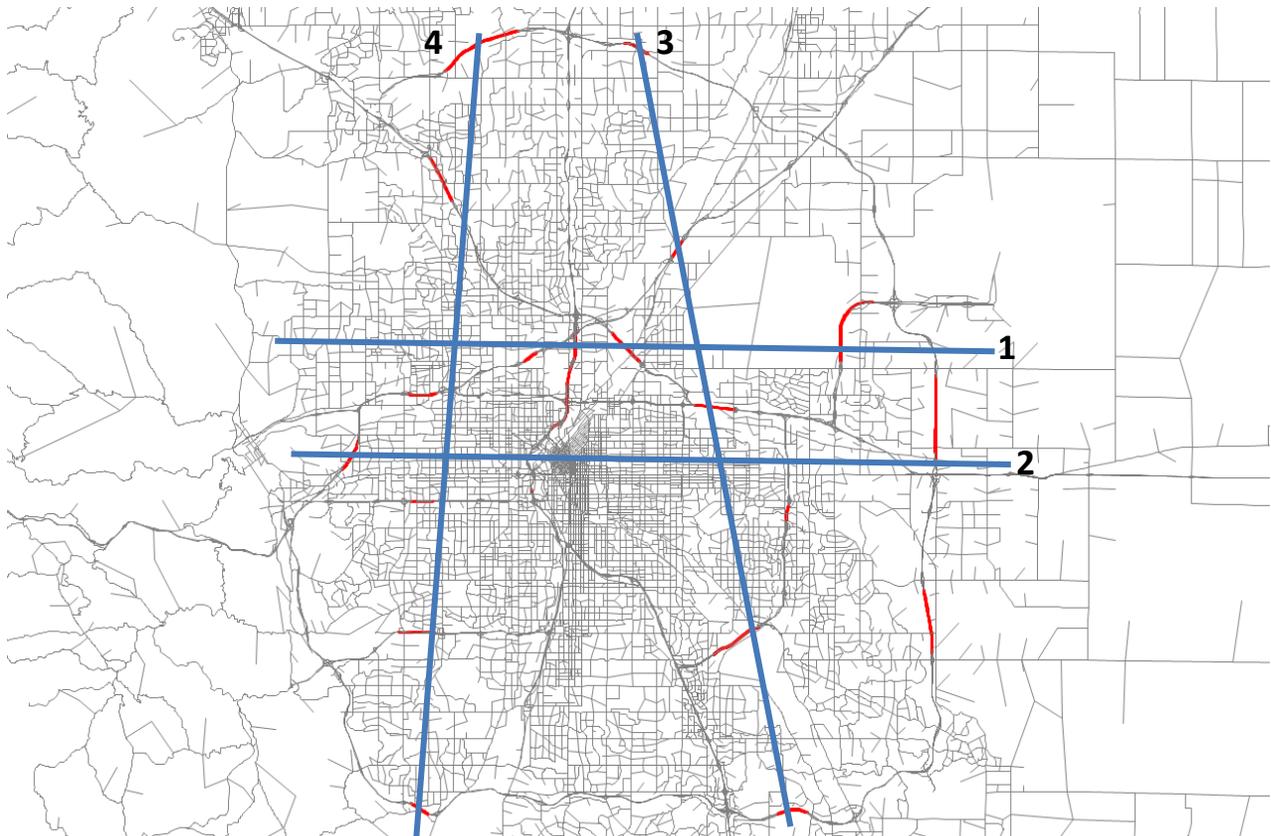


Table 12. Screenline Counts and FOCUS Calib36 Model Demand

| Period | AM | | | PM | | | MD | | | AM, MD and PM | | |
|--------|--------|---------|--------|--------|---------|--------|--------|---------|--------|---------------|---------|--------|
| | Count | Calib36 | % Diff | Count | Calib36 | % Diff | Count | Calib36 | % Diff | Count | Calib36 | % Diff |
| 1 | 30,383 | 77,634 | 156% | 33,136 | 127,195 | 284% | 50,835 | 124,906 | 146% | 114,354 | 338,803 | 196% |
| 2 | 32,782 | 69,636 | 112% | 32,681 | 108,763 | 233% | 65,469 | 89,356 | 36% | 130,932 | 283,767 | 117% |
| 3 | 33,220 | 81,825 | 146% | 35,498 | 129,449 | 265% | 50,935 | 99,288 | 95% | 119,653 | 324,011 | 171% |
| 4 | 27,384 | 76,093 | 178% | 36,351 | 122,301 | 236% | 52,302 | 99,559 | 90% | 116,037 | 293,727 | 153% |

The model demand in AM, MD and PM periods is significantly greater than traffic counts. Part of the difference between model demand and traffic counts is possibly due to a difference in definition of time period between the model and traffic counts. On a daily basis (with the exclusion of EL period), the modeled volumes crossing these screenlines are greater than the counts. The selected screenlines include only freeways, which could mean that the model is over-assigning demand to the freeways.

Test I: The BPR volume-delay function currently used by the DRCOG FOCUS model is:

$$t_c = t_f * \left(1 + \alpha * \left(\frac{v}{c}\right)^\beta\right)$$

where,

t_c = congested link travel time

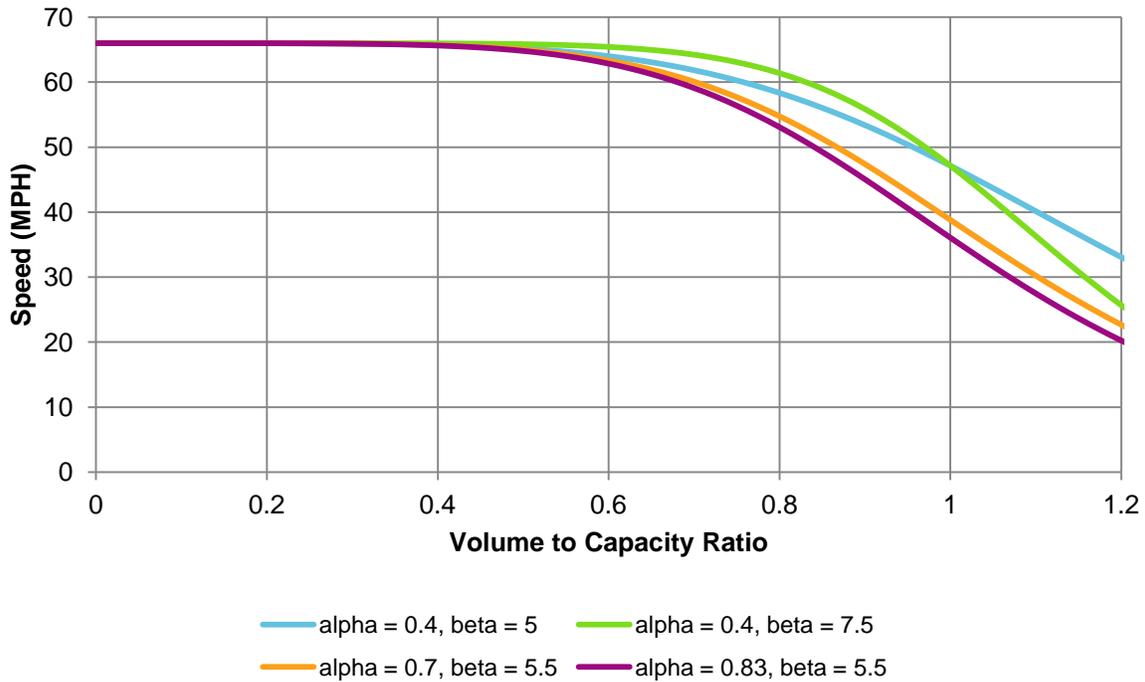
t_f = free-flow link travel time (if using speed feedback, it is the speed from previous iteration loop)

$\left(\frac{v}{c}\right)$ = link volume-capacity ratio

α, β = volume-delay function parameters

In the original FOCUS model (Calib36), highway facility links (FACILITY_TYPE = 1) were coded with three different α and β combinations: 0.4 and 5.0, 0.4 and 7.5, and 0.7 and 5.5. A test assignment is run with $\alpha = 0.83$ and $\beta = 5.5$. This change to α and β made the reduction in link speeds more sensitive to congestion at near capacity conditions, as shown in Figure 8. For the purpose of this test, VOT in the skimming and assignment steps were varied by purpose and income (similar to Test H).

Figure 8. Speed – Flow Curves for Different α and β parameter combinations



The change in α and β parameters did not improve the flows on toll facilities, as shown in Table 13.

Table 13. Sensitivity of FOCUS Highway Assignment to BPR Parameters

| Location | Count | FOCUS Calib36 | Test I | % Difference from Count | % Difference from Calib36 |
|--|--------|---------------|--------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | 14,591 | -63% | 7% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | 8,346 | -49% | 447% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | 15,774 | -20% | 185% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | 7,127 | -73% | 331% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | 7,490 | -53% | 309% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | 238 | -72% | 2298% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | 2,527 | -70% | 222% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 3,057 | 19% | 9% |
| I-25: 58th Ave | 12,833 | 7,857 | 7,084 | -45% | -10% |
| I-25: 70th Ave | 12,809 | 3,217 | 2,779 | -78% | -14% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 4,834 | 10,666 | -55% | 121% |
| Northwest Pkwy | 8,508 | 784 | 2,527 | -70% | 222% |

| | | | | | |
|------|--------|-------|-------|------|------|
| I-25 | 12,821 | 5,537 | 4,931 | -62% | -11% |
| All | 14,961 | 3,719 | 6,042 | -60% | 62% |

Test J: A new Test J is designed to test the sensitivity of the FOCUS highway assignment to VOT when it is varied by purpose and income. The new Test J is designed as Test H with 1.5 times the VOT for each purpose-income category. The results, shown in Table 14, suggest that the toll facility volumes are sensitive to VOT in the FOCUS highway assignment setup. The toll facility volumes in Test J are closer to counts than with Test C and Test F. Test J performed better than Test D for E-470 and Northwest Parkway facilities.

Table 14. FOCUS Daily Highway Travel Demand with Skimming and Assignment using 1.5 times the VOT in Test H

| Location | Count | FOCUS Calib36 | Test J | % Difference from Count | % Difference from Calib36 |
|--|--------|---------------|--------|-------------------------|---------------------------|
| E-470: @ Toll Plaza A | 38,916 | 13,622 | 28,914 | -26% | 112% |
| E-470: @ Toll Plaza C | 16,457 | 1,527 | 12,834 | -22% | 740% |
| E-470: @ Toll Plaza D | 19,755 | 5,540 | 22,557 | 14% | 307% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 26,647 | 1,652 | 14,260 | -46% | 763% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 15,993 | 1,831 | 11,057 | -31% | 504% |
| Northwest Pkwy: e/o Sheridan Pkwy | 864 | 10 | 439 | -49% | 4320% |
| Northwest Pkwy: Main Plaza w/o Lowell Blvd | 8,508 | 784 | 6,650 | -22% | 748% |
| Northwest Pkwy: w/o US-287 | 2,566 | 2,804 | 4,220 | 64% | 51% |
| I-25: 58th Ave | 12,833 | 7,857 | 7,891 | -39% | 0% |
| I-25: 70th Ave | 12,809 | 3,217 | 3,319 | -74% | 3% |
| Average Corridor Flows | | | | | |
| E-470 | 23,554 | 4,834 | 17,924 | -24% | 271% |
| Northwest Pkwy | 8,508 | 784 | 6,650 | -22% | 748% |
| I-25 | 12,821 | 5,537 | 5,605 | -56% | 1% |
| All | 14,961 | 3,719 | 10,060 | -33% | 171% |

The toll facility model demand in some of the above test scenarios are compared to observed counts by AM, MD and PM time periods in Table 15. Calib36 consistently underestimates demand on the toll facilities in all time periods. Test C significantly overestimates demand on E-470, NWP and I-25. Test E does not improve upon Calib36 in AM and PM, but moves the E-470 and NWP demand towards the count in MD (I-25 is incorrectly modeled in off-peak as explained earlier in the memo). Test J performs better than the rest: overestimates average AM facility demand by 40% or less, estimates average PM facility demand within 15%, and underestimates average MD facility demand by 25% or less.

Table 15. AM, MD and PM Highway Demand for Calib36 and Select Test Scenarios

| Location | Count | Model Demand | | | | | | % Difference from Count | | | | | |
|--|--------|--------------|--------|--------|--------|--------|--------|-------------------------|--------|--------|--------|--------|--------|
| | | Calib36 | Test C | Test D | Test E | Test F | Test J | Calib36 | Test C | Test D | Test E | Test F | Test J |
| AM | | | | | | | | | | | | | |
| E-470: @ Toll Plaza A | 6,458 | 6,073 | 24,257 | 10,108 | 6,443 | 6,062 | 10,027 | -6% | 276% | 57% | 0% | -6% | 55% |
| E-470: @ Toll Plaza C | 2,212 | 644 | 8,071 | 2,574 | 651 | 1,305 | 2,560 | -71% | 265% | 16% | -71% | -41% | 16% |
| E-470: @ Toll Plaza D | 3,228 | 2,159 | 16,503 | 4,012 | 2,243 | 2,819 | 4,165 | -33% | 411% | 24% | -30% | -13% | 29% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 4,418 | 846 | 15,316 | 3,404 | 1,012 | 1,499 | 3,470 | -81% | 247% | -23% | -77% | -66% | -21% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 2,264 | 621 | 9,056 | 1,773 | 660 | 1,098 | 1,806 | -73% | 300% | -22% | -71% | -52% | -20% |
| NORTHWEST PKWY: Main Plaza w/o Lowell Blvd | 1,234 | 309 | 6,875 | 1,373 | 368 | 693 | 1,269 | -75% | 457% | 11% | -70% | -44% | 3% |
| Average Corridor Flows | | | | | | | | | | | | | |
| E-470 | 3,966 | 2,959 | 16,277 | 5,565 | 3,112 | 3,395 | 5,584 | -25% | 310% | 40% | -22% | -14% | 41% |
| Northwest Pkwy | 1,234 | 309 | 6,875 | 1,373 | 368 | 693 | 1,269 | -75% | 457% | 11% | -70% | -44% | 3% |
| MD | | | | | | | | | | | | | |
| E-470: @ Toll Plaza A | 12,137 | 74 | 194 | 243 | 1,588 | 942 | 4,110 | -99% | -98% | -98% | -87% | -92% | -66% |
| E-470: @ Toll Plaza C | 4,630 | 22 | 6,093 | 3,239 | 2,217 | 3,028 | 4,159 | -100% | 32% | -30% | -52% | -35% | -10% |
| E-470: @ Toll Plaza D | 6,537 | 172 | 17,838 | 6,092 | 4,838 | 5,416 | 8,711 | -97% | 173% | -7% | -26% | -17% | 33% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 6,933 | 29 | 2,903 | 2,070 | 1,389 | 2,175 | 3,974 | -100% | -58% | -70% | -80% | -69% | -43% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 4,778 | 9 | 11,824 | 2,702 | 2,290 | 2,559 | 4,511 | -100% | 147% | -43% | -52% | -46% | -6% |
| NORTHWEST PKWY: Main Plaza w/o Lowell Blvd | 2,758 | 20 | 10,364 | 412 | 133 | 213 | 2,507 | -99% | 276% | -85% | -95% | -92% | -9% |
| Average Corridor Flows | | | | | | | | | | | | | |
| E-470 | 7,768 | 89 | 8,042 | 3,192 | 2,881 | 3,129 | 5,660 | -99% | 4% | -59% | -63% | -60% | -27% |
| Northwest Pkwy | 2,758 | 20 | 10,364 | 412 | 133 | 213 | 2,507 | -99% | 276% | -85% | -95% | -92% | -9% |
| PM | | | | | | | | | | | | | |
| E-470: @ Toll Plaza A | 12,131 | 7,443 | 36,973 | 14,524 | 8,122 | 7,946 | 13,790 | -39% | 205% | 20% | -33% | -34% | 14% |
| E-470: @ Toll Plaza C | 4,560 | 851 | 10,608 | 4,008 | 956 | 2,308 | 4,389 | -81% | 133% | -12% | -79% | -49% | -4% |
| E-470: @ Toll Plaza D | 5,717 | 3,207 | 20,679 | 6,778 | 3,377 | 4,485 | 6,628 | -44% | 262% | 19% | -41% | -22% | 16% |
| E-470: s/o Jewell Ave @ Toll Plaza B | 7,941 | 764 | 19,413 | 5,111 | 866 | 2,459 | 5,184 | -90% | 144% | -36% | -89% | -69% | -35% |
| E-470: w/o Riverdale Rd @ Toll Plaza E | 4,318 | 1,197 | 11,182 | 3,411 | 1,347 | 2,260 | 3,415 | -72% | 159% | -21% | -69% | -48% | -21% |
| NORTHWEST PKWY: Main Plaza w/o Lowell Blvd | 2,753 | 446 | 6,995 | 2,480 | 504 | 1,294 | 2,378 | -84% | 154% | -10% | -82% | -53% | -14% |
| Average Corridor Flows | | | | | | | | | | | | | |
| E-470 | 7,469 | 3,834 | 22,753 | 8,437 | 4,152 | 4,913 | 8,269 | -49% | 205% | 13% | -44% | -34% | 11% |
| Northwest Pkwy | 2,753 | 446 | 6,995 | 2,480 | 504 | 1,294 | 2,378 | -84% | 154% | -10% | -82% | -53% | -14% |

6. Summary:

A summary description of the price sensitivity tests discussed above is provided in Table 16. Table 17 also shows a comparison of highway assignment results for Calib36 and the price sensitivity tests to observed counts. The average toll facility volumes are also plotted using a spider plot in Figure 9. For the spider plot, Test A results are omitted as they are all zero. Test B results are omitted to keep the scale manageable. The average corridor flows for E-470, Northwest Parkway, I-25 and an average for the three corridors from the various tests are plotted along the four vertices of the plot. The corresponding count is plotted as the blue line. The closer a vertex corresponding to a test scenario is closer to the count vertex, closer is the test scenario assignment flow to the observed count. As the figure shows, Test G and Calib36 produced similar results, and Test F and Test H produced similar results suggesting that VOT in skimming did not significant impact assignment flows. Test H and I produced similar results, suggesting that changes to the BPR volume-delay function parameters did not make a significant difference to the assignment flows. Test J resulted in corridor flows that are closer to the count than other tests.

Table 16. Summary Description of the Price Sensitivity Tests

| Price Sensitivity Test | Description |
|------------------------|---|
| Test A | Zero VOT: Travelers aim to minimize total cost consisting of tolls and distance-based auto operating costs (i.e., no travel time considerations). |
| Test B | Infinite VOT: Travelers aim to minimize only travel time (i.e., costs are ignored). |
| Test C | Twice the VOT in Calib36 |
| Test D | VOT by income borrowed from the COMPASS 4.0 model |
| Test E | VOT in the Highway Assignment is based on the analysis done as part of Task A (memo titled "US 36 Stated Preference Survey Value of Time Analysis") |
| Test F | VOT is varied by purpose and income within the FOCUS highway assignment, reflecting the variation of VOT in the Tour Mode Choice |
| Test G | Highway Skimming using VOT by purpose and income. New highway trips assigned using DRCOG FOCUS default VOT |
| Test H | Highway Skimming using VOT by purpose and income. New highway trips assigned using VOT by purpose and income (as used for highway skimming) |
| Test I | Test H with BPR VDF parameters changed to $\alpha = 0.83$ and $\beta = 5.5$ for highway facilities (FACILITY_TYE =1) |
| Test J | Test H with 1.5 times the VOT for each purpose-income category |

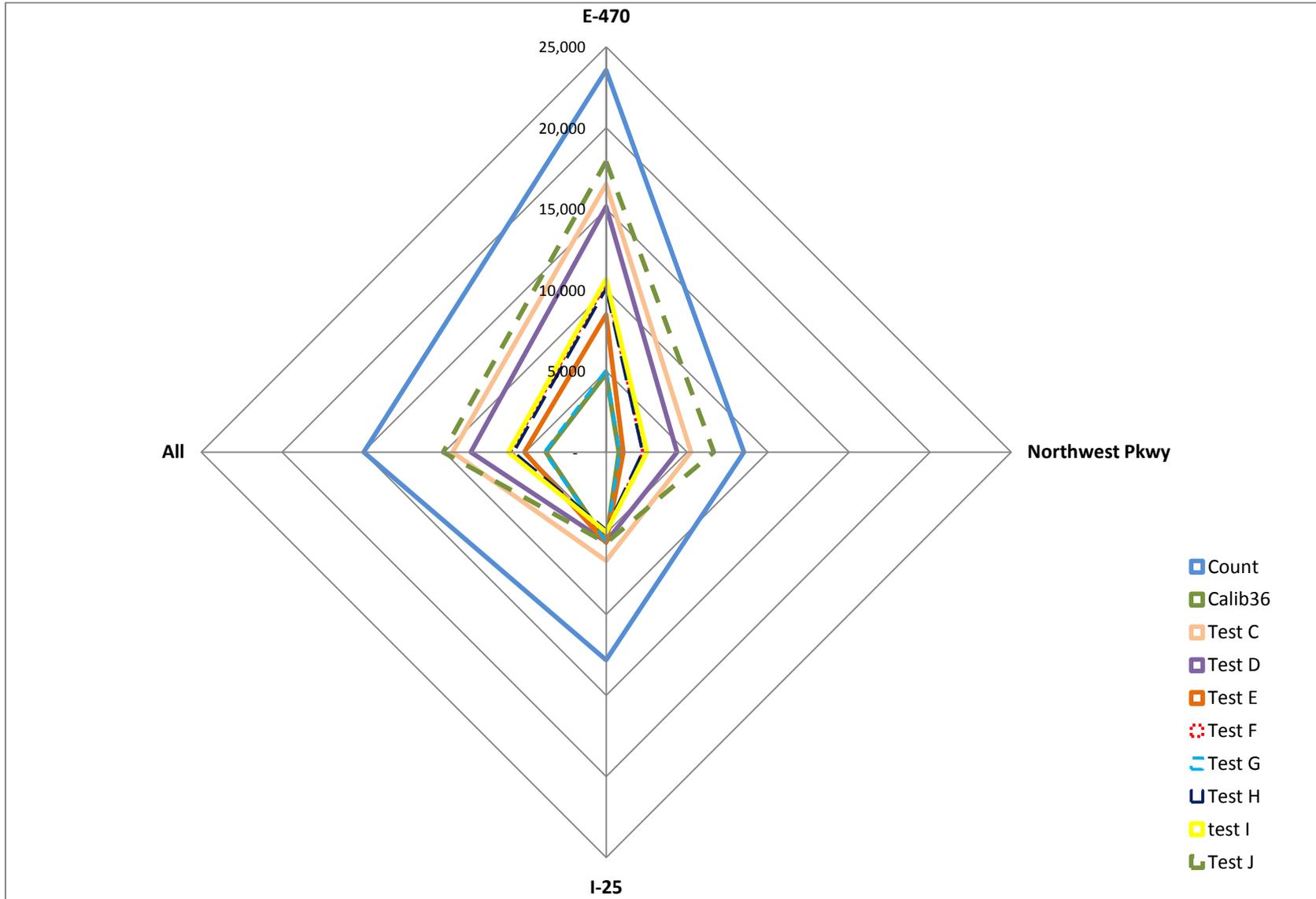
The results from Tests A to J as well as prior Compass model assignment setups indicate that the toll facility volumes are sensitive to value of time during path assignment and this sensitivity varies by income and purpose, especially for work and DIA trips. The analysis of the Stated Preference Survey (Task A) also showed indications of variation of VOT by income, purpose and time of day.

It is also observed from existing toll road operations and surveys across the country that for travelers who choose to pay toll, the benefits derived for the additional cost are not solely due to the travel time savings and part of the benefits from a priced facility are derived from the reliability offered by the tolled facilities. Some users also choose the tolled facility due to additional perceived benefits such as safety and comfort. The tests done so far for this study did not include these perceived reliability, safety, and comfort benefits. In subsequent price sensitivity tests, these perceived benefits will be included akin to a toll road bonus.

Table 17. Comparison of Toll Facility Daily Volumes in Price Sensitivity Tests to Observed Count

| Average Corridor Flows | Count | Percentage Difference From Count | | | | | | | | | | |
|------------------------|--------|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| | | Calib36 | Test A | Test B | Test C | Test D | Test E | Test F | Test G | Test H | Test I | Test J |
| E-470 | 23,554 | -79% | -100% | 205% | 79% | -36% | -64% | -56% | -79% | -57% | -55% | -24% |
| Northwest Pkwy | 8,508 | -91% | -100% | 434% | 185% | -49% | -88% | -73% | -90% | -74% | -70% | -22% |
| I-25 | 12,821 | -57% | -100% | 37% | 50% | -57% | -56% | -61% | -57% | -63% | -62% | -56% |
| All | 14,961 | -75% | -100% | 200% | 91% | -44% | -66% | -61% | -75% | -62% | -60% | -33% |

Figure 9. Daily Highway Demand with Skimming and Assignment using Different VOT



7. Next Steps

A few next steps to further study the sensitivity of the FOCUS model components to pricing are suggested below.

1. Currently, auto operating cost is calculated using a rate that depends on the level of congestion. A test run with the auto operating cost that varies linearly with distance can give some insight into the sensitivity of the model to auto operating cost.
2. As explained above, the tolls coded in the highway network are not exactly representative of the current toll regime. Hence, toll facility demand from the model cannot be strictly compared with the counts. While the above tests provide a fairly good means to understand the sensitivity of the model assignment and skimming processes to price, a more accurate coding of tolls, such as coding the toll at entry and exit points, differentiating the toll rates by the time of day, etc. will help bring the toll facility demands closer to observed counts.
3. Test the sensitivity of transit paths to value of time. The VOT in transit skimming is currently categorized by peak and off-peak periods. As a next step, transit skimming will be tested with VOT categorized by four time periods, and VOT to be half and twice the VOT in Calib36. The value of time will be set to be the same for AM and PM peak periods, and similarly, for MD and EL periods.
4. Build a toll choice model within highway assignment step based on a continuous VOT distribution (lognormal curve with specified mean and standard deviation). The VOT distribution(s) will be estimated based on findings for Task A. A conceptual framework is illustrated in Figure 10. Since the Denver region currently does not have dynamic tolls in operation, we propose to implement the inner loop of the model, where the toll rates are already set, and the toll/no-toll skims feed into the choice of deciding toll paying and non-paying vehicles, which are then assigned to the network. If and when dynamic tolls need to be modeled, the outer loop can be included in the toll choice model, where a feedback mechanism can aid in setting toll rates.
5. Consider including value of time skims in the activity generation and tour location choice process. This is currently not included in the scope of work.

Figure 10. Proposed concept for a Toll Choice Model

